GROUNDWATER AND PUBLIC POLICY LEAFLET SERIES

This series of seventeen leaflets is part of a set of educational materials on rural groundwater quality issues developed by the Groundwater Policy Education Project. This ASCII version of the leaflet series contains the complete text, but none of the graphics found in the original. Leaflets may be purchased from the Freshwater Foundation, Spring Hill Center, 725 County Road Six, Wayzata, Minnesota 55391, Telephone: (612) 449-0092. Reproduction and publication, in whole or in part, of adaptation for specific audiences is encouraged. Authors should be properly cited, with the Groundwater Policy Education Project identified as the source.

The Groundwater Policy Education Project is a joint effort of Cooperative Extension, the Freshwater Foundation, and the Soil and Water Conservation Society. These organizations joined together to create educational materials that would increase the abilities of citizens and local and state officials to make informed groundwater policy decisions.

#3: SOURCES AND EXTENT OF GROUNDWATER CONTAMINATION

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Groundwater is an important source of drinking water for more than half of the nation+s population and nearly all its rural population. In recent years, widespread reports of bacteria, nitrate, synthetic organic chemicals and other pollutants in groundwater have increased public concern about the quality of groundwater. What do we know and what don't we know - about groundwater quality? What causes groundwater contamination, and to what extent are the nation+s groundwater supplies at risk?

How Much Do We Depend on Groundwater?

According to 1985 U.S. figures, groundwater provides an estimated:

- 22 percent of all freshwater withdrawals
- 53 pecent of drinking water for the total population and 97 percent of drinking water for the rural population
- 40 percent of public water supply withdrawals
- 46 percent of domestic and commercial use
- 24 percent of industrial and mining use
- 34 percent of agricultural use (mostly for irrigation)

How Susceptible Is Groundwater To Contamination?

About one-fourth of the average 4.2 trillion gallons of precipitation that falls each day on the conterminous United States infiltrates the soil and recharges local aquifers, the sediments and rocks that store and transport groundwater. In general, shallow, permeable water table aquifers are the most susceptible to contamination, but susceptibility of all aquifers to contamination is determined largely by such site-specific characteristics as:

- distance from the contamination source to the aquifer and residence time of the water in the unsaturated zone
- potential of a particular contaminant to biodegrade and decompose
- amount of precipitation, which affects recharge and the rate at which contaminants move downward
- evapotranspiration, which in recharge areas may decrease the amount of water that moves downward to the aquifer

WHAT CAUSES GROUNDWATER CONTAMINATION?

Natural Sources

Groundwater contamination can occur in many ways and from many sources, both natural and human induced. Groundwater commonly contains one or more naturally occurring chemicals, leached from soil or rocks by percolating water, in concentrations that exceed federal or state drinking water standards or otherwise impair its use.

Dissolved Solids and Chloride

One of the most common water quality concerns is the presence of dissolved solids and chloride in concentrations that exceed the recommended maximum limits in federal secondary drinking water standards: 500 mg/L (milligrams per liter or approximately equivalent to parts per million) for dissolved solids and 250 mg/L for chloride. Such concentrations are found at the seaward ends of all coastal aquifers and are quite common in aquifers at depths greater than a few hundred feet below the land surface in many parts of the United States.

Iron and Manganese

Although not particularly toxic, iron and manganese in concentrations greater than the limits for federal secondary drinking water standards (0.3 mg/L for iron and 0.05 mg/L for manganese) can impair the taste of water; stain plumbing fixtures, glassware and laundry; and form encrustrations on well screens, thereby reducing well-pumping efficiency.

Nitrate-Nitrogen

Most groundwater not affected by human activity contains less than 10 mg/L nitrate-nitrogen, the maximum concentration allowed by federal primary drinking water standards. Nationwide, nitratenitrogen concentrations of less than 0.2 mg/L generally represent natural conditions, whereas values greater than 3 mg/L may indicate the effects of human activities.

Although relatively nontoxic, nitrate may be reduced by bacteria to nitrite in the intestines of newborn infants and cause the disease methemoglobinemia. Nitrate also can react with amines in the human body to form N-nitrosamines, carcinogenic chemicals known to induce tumors in laboratory animals and thought to be linked to human cancers.

Human Activities

Contaminants can enter groundwater from more than 30 different generic sources related to human activities. These sources commonly are referred to as either point or nonpoint sources. Point sources are localized in areas of an acre or less, whereas nonpoint sources are dispersed over broad areas.

The most common sources of human-induced groundwater contamination can be grouped into four categories: waste disposal practices; storage and handling of materials and wastes; agricultural activities; and saline water intrusion.

Waste Disposal Practices

Perhaps the best-known sources of groundwater contamination are associated with the storage or disposal of liquid and solid wastes. The organic substances most frequently reported in groundwater as resulting from waste disposal, in decreasing order of occurrence, are:

- trichloroethylene (TCE)
- chloroform
- benzene
- pentachlorophenol
- tetrachloroethylene (PCE)
- creosote

- phenolic compounds
- 1,1,1-trichloroethane
- toluene
- xylene

Waste disposal can take a number of forms:

- septic systems
- municipal and industrial landfills
- surface impoundments
- waste-injection wells
- direct application of stabilized wastes to the land

In addition to these regulated forms of disposal, a considerable amount of unregulated disposal, such as illegal dumping and accidental spills, contributes to groundwater contamination.

SEPTIC SYSTEMS. Septic systems are the largest source by volume of waste discharged to the land. These systems are sources of bacteria, viruses, nitrate, phosphorus, chloride and organic substances, including organic solvents such as trichloroethylene that are sold commercially to "clean" the systems.

In 1980, about 22 million domestic disposal systems were in operation, and about one-half million new systems are installed each year. It is estimated that from one-third to one-half of existing systems could be operating improperly because of poor location, design, construction or maintenance practices.

Even when operating properly, systems can be spaced so densely that their discharge exceeds the capacity of the local soil to assimilate the pollutant loads. Because the 10- to-15-year design life of many septic systems built during the 1960s and 1970s is now exceeded, groundwater contamination caused by septic system failure probably will increase in the future.

LANDFILLS. About 150 million tons of municipal solid waste and 240 million tons of industrial solid waste are deposited in 16,400 landfills each year. Some hazardous waste material may be deposited in municipal landfills and underlying groundwater may become contaminated. Wastes deposited at industrial landfills include a large assortment of trace metals, acids, volatile organic compounds and pesticides, which may cause significant local contamination.

SURFACE IMPOUNDMENTS. Surface impoundments are used to store, treat or dispose of oil and gas brines, acidic mine wastes, industrial wastes (mainly liquids), animal wastes, municipal treatment plant sludges and cooling water. For the most part, these impoundments contain nonhazardous wastes; however, hazardous wastes are known to be treated, stored and disposed of by 400 facilities involving about 3,200 impoundments. Some of these impoundments have significant potential for contaminating groundwater.

INJECTION WELLS. In some parts of the country, injection wells dispose of liquid wastes underground. Of particular concern is the widespread use of drainage wells to dispose of urban stormwater runoff and irrigation drainage. Contaminants associated with drainage wells include suspended sediments; dissolved solids; bacteria; sodium; chloride; nitrate; phosphate; lead; and organic compounds, including pesticides.

LAND APPLICATION OF WASTES. In many places, solid and liquid wastes are placed or sprayed on the land, commonly after treatment and stabilization. The U.S. Environmental Protection Agency (EPA) has estimated that more than 7 million dry tons of sludge from at least 2,463 publicly owned waste treatment plants are applied to about 11,900 parcels of land each year. Contamination can occur from improper land-disposal techniques.

Storage and Handling of Materials and Wastes

Groundwater contamination as the result of storage and handling of materials includes leaks from both above-ground and underground storage tanks, as well as unintentional spills or poor housekeeping practices in the handling and transfering of materials on industrial and commercial sites.

LEAKING UNDERGROUND STORAGE TANKS. Between 2.4 and 4.8 million steel tanks are used to store petroleum products, acids, chemicals, industrial solvents and other types of waste underground. The potential of these tanks to leak increases with age. About 20 percent of existing steel tanks are more than 16 years old, and estimates of the total number that presently leak petroleum products range from 25 to 30 percent. Underground storage tanks appear to be a leading source of benzene, toluene and xylene contaminants, all of which are organic compounds in diesel and gasoline fuels.

TRANSPORTING AND STOCKPILING. Many materials and wastes are transported and then temporarily stored in stockpiles before being used or shipped elsewhere. Precipitation can leach potential contaminants from such stockpiles; storage containers can corrode and leak; and accidental spills can occur - as many as 10,000 to 16,000 per year, according to EPA estimates.

MINING PRACTICES. Mining of coal, uranium and other substances and the related mine spoil can lead to groundwater contamination in several ways:

- Shafts and tunnels can intersect aquifers.
- Exposing coal to oxygen can form sulfuric acid, which can degrade water quality.
- Contaminants from tailings can leach into groundwater.

OIL-WELL BRINES. Since the 1800s, hundreds of thousands of exploratory and production wells have been drilled for oil and gas in the United States. During production, oil wells produce brines that are separated from the oil and stored in surface impoundments. EPA estimates that 125,100 brine-disposal impoundments exist that might affect local groundwater supplies.

Agricultural Activities

Agriculture is one of the most widespread human activities that affects the quality of groundwater. In 1987, about 330 million acres were used for growing crops in the United States, of which 45 million acres were irrigated.

FERTILIZERS. During the 1960s and 1970s, nitrogen, phosphorus and potassium fertilizer use steadily increased to a peak of 23 million tons in 1981. By 1987, however, fertilizer use had declined to 19.2 million tons, reflecting the large number of acres withdrawn from production as part of the Conservation Reserve Program and other government programs.

If nitrogen supply exceeds nitrogen uptake by crops, excess nitrogen can be leached to groundwater. In such areas, local nitratenitrogen concentrations may exceed the federal drinking water standard of 10 mg/L.

PESTICIDES. Pesticides have been used since the 1940s to combat a variety of agricultural pests. Between 1964 and 1982, the amount of active ingredients applied to croplands increased 170 percent. Herbicide usage peaked in 1982, and since then has declined from about 500 million pounds of active ingredients per year to about 430 million pounds in 1987.

In addition to crop applications, infiltration of spilled pesticides can cause contamination in locations where pesticides are stored, and where sprayers and other equipment used to apply pesticides are loaded and washed.

Pesticides most frequently detected in groundwater are the fumigants ethylene dibromide (EDB) and 1,2-dichloropropane; the insecticides aldicarb, carbofuran and chlordane; and the herbicides alachlor and atrazine.

FEEDLOTS. Feedlots confine livestock and poultry and create problems of animal-waste disposal. Feedlot wastes often are collected in impoundments from which they might infiltrate to groundwater and raise nitrate concentrations. Runoff from farmyards may also directly enter an aquifer along the outside of a poorly sealed well casing.

IRRIGATION. Percolation of irrigation water into soils dissolves soil salts and transports them downward. Evapotranspiration of applied water from the root zone concentrates salts in the soil and increases the salt load to the groundwater.

Chemigation, the practice of mixing and distributing pesticides and fertilizers with irrigation water, may cause contamination if more chemicals are applied than crops can use. It may also cause local contamination if chemicals back-siphon from the holding tank directly into the aquifer through an irrigation well.

SALINE WATER INTRUSION. The encroachment of saline water into the freshwater part of an aquifer is an ever-present threat when water supplies are developed from the highly productive coastal plain aquifers of the United States, or from aquifers underlain by saline water in the interior of the country. Local incidents of saline water intrusion have occurred on all coasts of the United States.

How Extensive Is Groundwater Contamination?

Assessment of the extent of groundwater contamination is difficult, due to such factors as limited and inconsistent access to the water (usually dependent on wells and springs); the potential for bias in existing data (if originally collected to explore a particular water quality problem); incomplete information about the well (did the well draw from more than one aquifer?); and inconsistent methods of sampling and analysis.

It is also important to keep in mind that the trend of increasing reports of detections of contaminants in groundwater is largely due to the intensive search for contaminants now under way by many state agencies, as well as continued improvements in the sensitivity of analytical methods used to measure the concentration of contaminants.

The volume of groundwater within 2500 feet of the surface has been estimated at 100 quadrillion gallons, or about 16 times the volume of the Great Lakes. Of this amount, at least half is too saline from natural causes to use for drinking water, although some of itmay be suitable for other uses. The total amount of the remaining groundwater that is contaminated is unknown, although EPA estimates the amount contaminated by point sources to be 2-3 percent.

Recent U.S. Geological Survey studies have made the following assessments:

- The United States has large amounts of potable water available for use. Locally, how ever, high concentrations of a variety of toxic metals, organic chemicals and petroleum products form plumes around such point sources as leaking underground storage tanks, waste disposal sites and chemical- or
- wastehandling areas. These types of problems generally occur in urban or industrialized areas, although they are found occasionally in rural areas.
- Large regions have been identified in which contaminants, derived from nonpoint sources and often at minimum detectable levels, are present in many shallow wells throughout a given area. In a small percentage of wells, such contaminants as nitrate may exceed drinking water standards or health advisories.
- Generally, such nonpoint source contamination is associated with densely populated urban areas, agricultural land uses and concen trations of septic systems. Furthermore, such contamination commonly affects only the shallowest aquifers.
- 20 percent of 124,000 wells sampled over the past 25 years contained a maximum nitrate nitrogen concentration greater than 3 mg/L, suggesting the effects of human activities. 6 percent of the samples exceeded the federal drinking water standard for nitrate-nitrogen of 10 mg/L.
- Although 44 state summaries in the U.S. Geological Survey's 1986 National Water Summary on groundwater quality mention detection of pesticides in groundwater, data are insufficient to draw conclusions about the extent of contamination. The state sum maries do, however, express widespread concern that the frequency of detections and the concentrations of pesticides will increase over time.

The U.S. EPA has compiled reports on the occurrence of 46 pesticides in groundwater. In 26 states, one or more pesticides have been detected in groundwater that can be attributed to normal agricultural use. The most commonly detected pesticides are atrazine and aldicarb.

EPA currently is conducting its National Pesticide Survey to provide a nationwide estimate of the occurrence of pesticides in drinking water wells. The survey includes the collection of water samples from a statistically representative sample of community water system wells (600) and private wells (750).

Interim results show that 6 of 180 community well samples collected thus far and 9 of 115 private well samples had detectable pesticide residues. Of the 15 wells that had detectable levels of pesticides, 3 had concentrations that exceeded lifetime health advisory levels established by EPA. Of 295 wells sampled thus far, samples from 8 wells had nitrate-nitrogen concentrations that exceeded the 10 mg/L drinking water standard. All 8 samples were from private wells. Statistically reliable estimates of the percentage of wells

containated will be available when the survey results are released in late 1990.

SUMMARY: How Contaminated Is Groundwater?

Although little systematic information exists on the extent and severity of groundwater contamination, available evidence suggests that:

- The shallowest aquifers generally are at greatest risk of contamination, especially those where the overlying unsaturated zone is thin and permeable.
- Contamination of shallow aquifers by nitrates and synthetic organic chemicals is widespread in many areas.
- Shallow groundwater contamination can be related to land use.
- As yet, deeper aquifers, which commonly are used for public drinking water supplies, are relatively free from contamination.

Additional reports of groundwater contamination may be expected in the coming years, as federal, state and local agencies expand their groundwater quality monitoring programs using sophisticated analytical methods that can measure very small concentrations of contaminants. Groundwater moves very slowly,

and it may be years after remedial actions are taken before improvements in water quality are observed. For this reason, the enhancement of the quality of the nation's groundwater requires a long-term commitment.

More definitive assessments of groundwater quality will have to await the expansion of data-collection programs, the use of standard sampling and analytical procedures, research on the health risks associated wtih long-term exposure to very small concentrations of contaminants, and improvements in the computer models used to predict contaminant behavior.

Although current assessments of groundwater quality are far from definitive, they do suggest the widespread presence of shallow groundwater contamination. While we have much yet to learn about the sources and extent of contamination, the general principles and steps needed to protect groundwater from future contamination are well understood. Reductions of wastes, control of contamination sources and improved land management practices can significantly reduce the risk of contamination in the future.

(The unedited version of the paper on which this leaflet is based appears in the Journal of Soil and Water Conservation, 45(2)).

Recommended Further Readings

Groundwater Protection - Groundwater, Saving the Unseen Resource, and a Guide to Groundwater Pollution Problems, Causes and Government Responses. 1987.

The Conservation Foundation, Washington, D.C.

Basic Groundwater Hydrology. R.C. Heath. 1983. U.S. Geological Survey Water Supply Paper 2220.

Groundwater Regions of the United States. R.C. Heath. 1984. U.S. Geological Survey Water Supply Paper 2242.

National Water Quality Inventory: 1986 Report to Congress. 1987. U.S. Environmental Protection Agency. Report Number EPA-440/87/008.

National Water Summary 1986: Hydrologic Events and Groundwater Quality. 1988. U.S. Geological Survey Water Supply Paper 2325.

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